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NATO HLA Federation for Study of Air Vehicle Landings on Ships

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ABSTRACT*:* *In November 1997, the NATO Naval Armaments Group on Ship Design (NG/6) established a Specialist Team on Simulation Based Design and Virtual Prototyping (ST-SBDVP). The purpose of the Team is to share information on the benefits, risks, and costs of instituting the technologies and processes of SBDVP applied to the acquisition of naval warships. A specific challenge undertaken by the Team is an experience-based study of inter-nation simulation interoperability, by applying the NATO-recommended High Level Architecture (HLA) to a military operations problem with significance to ship design. The Team has chosen to focus on vertical landings on warships by helicopters and unmanned aerial vehicles (UAVs), an operation of national interest to each of the Team nations. This problem incorporates daunting physics and military operations issues, which are dependent on understanding system interoperability between the ship, air vehicle, air vehicle control, and the landing system. Further, sufficient understanding of interoperability early in the system design process can be leveraged to optimize the ship/aircraft design in consideration of landing operations. This problem is therefore particularly conducive to examination via interoperable modeling and simulation.*

Three objectives the ST has in undertaking its study are: (1) to identify and correct any interoperability (technical, process, or culture) deficiencies in the conduct of a joint, allied nation federated simulation; (2) to introduce ST member nations to the development and execution of a simulation federation using HLA; and (3) to make advances, via international cooperation, toward a validated simulation of an important and potentially dangerous military operation, which encompasses very complex physics. To accomplish the objectives, the ST has set out to progress through the Federation Development and Execution Process (FEDEP) to develop a federation built of components from multiple nations. This paper reports progress of the team within the FEDEP up through development of a conceptual model and initial federation design.

1. Introduction

In November 1997, the NATO Naval Armaments Group on Ship Design (NG/6) established a Specialist Team on Simulation Based Design and Virtual Prototyping (ST-SBDVP). The purpose of the Team is to share information on the benefits, risks, and costs of instituting the technologies and processes of SBDVP applied to the acquisition of naval warships. A deliverable from the Team will be an Allied Naval Engineering Publication (ANEP), which will capture the ST's discussions, conclusions, and recommendations. During the course of the discussions, a second track was developed, namely, a multi-nation simulation interoperability study, using as the application test-bed manned and unmanned aircraft landings on warships, focusing on helicopters and unmanned aerial vehicles (UAV). This application was chosen because of the national interest in this military operation as expressed by every Team member and because of the possibility of modeling and

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simulating this dangerous operation as part of a joint Allied exercise.

The Specialist Team (ST) has four objectives in undertaking this study:

1. foster collaboration among NATO member and partner nations
2. identify and correct any interoperability deficiencies that might occur in the conduct of a joint, Allied nation federated simulation
3. introduce ST member nations to the development and execution of a simulation federation using the NATO-recommended High Level Architecture (HLA)
4. via international cooperation, make advances toward a validated simulation of an important and potentially dangerous military operation, which encompasses very complex physics.

The title of this interoperability study is NIREUS, or NATO/PfP Interoperability and Reuse Study. (PfP is an abbreviation for Partners for Peace.)

2. Conceptual Information Flow

The NIREUS Conceptual Information Flow Diagram shown in Figure 1 was developed by the ST members during mid-1999.

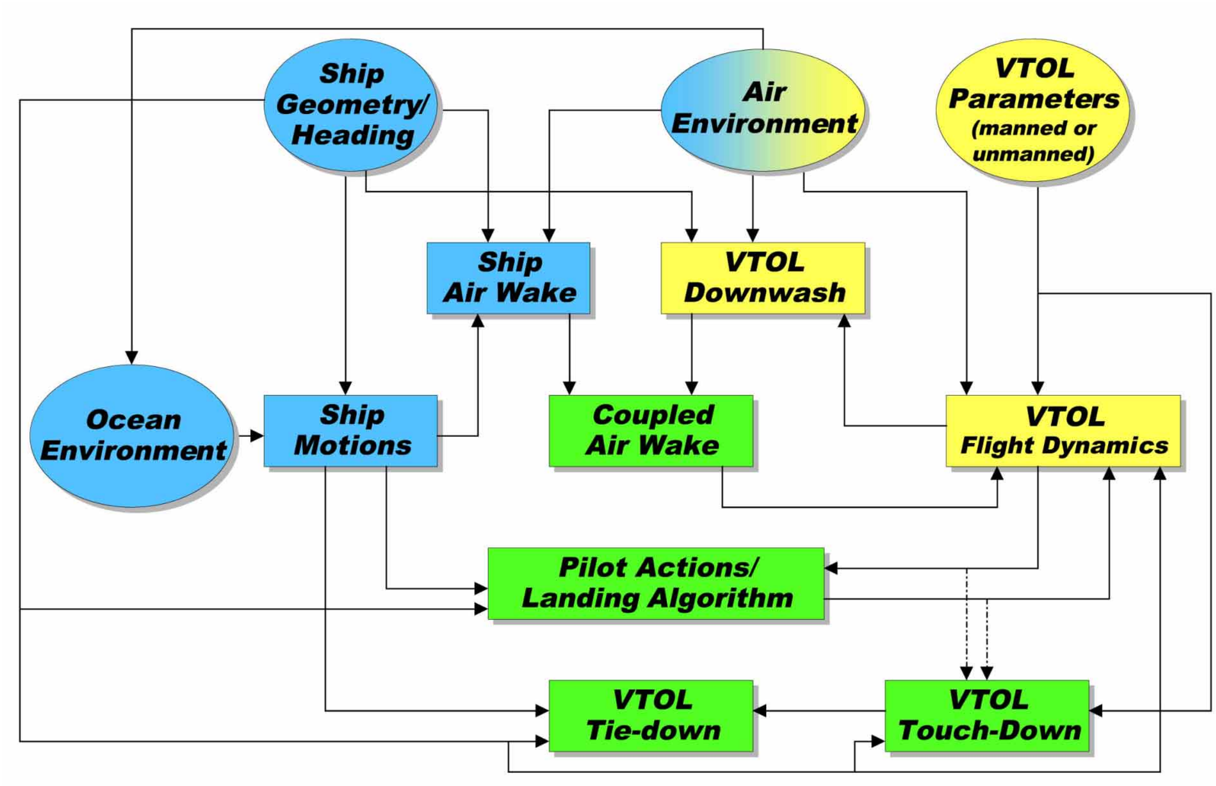

Figure 1. VTOL Ship Landing and Tie-Down: Conceptual Information Flow

It provides a high level conceptual model for the military operation to be performed. The color coding roughly maps the functions into three general modeling areas: ship modeling (blue), air vehicle modeling (yellow), and landing system modeling (green). In the most general case each of the objects shown would be interactive at runtime (e.g., wind gusts could occur, the ship may maneuver). However, the oval items are those which the ST expected from the beginning would be pre-runtime calculations for the foreseeable future. The conceptual information flow was further discussed and refined during the latter part of 1999, and another look was taken at which calculations should be conducted at runtime for the initial NIREUS Federation.

3. NIREUS Federation Requirements

It shouldn't come as any surprise to experienced M&S developers that the NIREUS requirements set is still evolving. This is even to the extent that participation by specific nations in NIREUS Federation development is uncertain. Some requirements are spelled out in the NIREUS study document, but many will be developed and articulated by multi-national modeling teams associated with the blue/yellow/green colored functions shown in the conceptual information flow diagram. Inputs from these groups will be forthcoming from intensive work sessions during Spring 2000.

Certain fundamental things are known about the initial NIREUS Federation. First, the federation will consist of Federates provided by multiple participating nations. Multi-national simulation interoperability may be demonstrated by simulating landing of a German UAV onto a British ship, for example. Second, within the scope of the project, 'simulation reuse' effectively means the participating countries gain experience in implementing distributed simulation using HLA. Thus, each participating nation will develop and provide their own federate(s) to the federation. That is, they learn to do for themselves. They develop federates for later reuse, but the most valuable reusable commodity is the experience gained in HLA federation development and execution.

Third, the Federation will be constructed of physics-based, engineering-level federates, but no new model development will be undertaken by the NIREUS team. Specifically, for coupled air wakes where the physics are little understood, the NIREUS team will not develop new algorithms or models for air wake calculation. We know this is a two-year project up against a ten-year physics problem. Therefore, we assume we are not out to make particular strides in representing computationally-intensive coupled air wakes in our NIREUS Federation. Rather, we are focused on demonstrating a multinational federation which conveys enabling experience to the participating nations for applying distributed, interoperable simulation to help solve the problem in the future.

3.1 Other Assumptions

To map the conceptual information into a nominal Federation layout, a further set of basic assumptions were defined. As expected, the natural environment for the initial NIREUS Federation will be assumed steady. Wind speed and direction will be assumed constant, and no wind gusts will occur. Similarly, the sea state will be constant, and no sea surges will occur. Also, the ship will pursue a constant heading without maneuvering. As a result, ship motion may be preprocessed prior to runtime. More so, the air wake generated by ship topside structures near the air vehicle landing zone may also be preprocessed. Both results are desired because the ship motion and air wake calculations are computationally intensive, and it's preferred to avoid executing those calculations at runtime. An even more complex physics issue that cannot now be executed at runtime is that the coupled airwake is time-dependent due to the changing relative positions and attitude of the ship and aircraft.

The scope of the NIREUS Federation will be limited to the landing operation of an air vehicle on an (aft) landing zone of a surface ship. So, it will be assumed the Federation will initialize with the ship and air vehicle pre-positioned at some geometry appropriate for landing approach. It is not yet known whether the initial NIREUS Federation will implement a piloted helicopter, a maritime UAV, or both. So, at this point the "pilot" in the conceptual model may be defined as: human-in-the-loop, human behavior representation, helicopter autopilot algorithms, or UAV computer algorithms.

With a developing set of requirements and assumptions in hand, the Conceptual Information Flow Diagram was reviewed. The idea was to take a prescient look forward at Federation Design to help facilitate efforts by the multinational working groups during Spring 2000. A look at a possible Federation design should be helpful as a springboard for discussions within the working teams. This should be an effective tool particularly because the primary team members are drawn from experienced modelers, but people highly inexperienced with distributed simulation and HLA.

4. Nominal Federation Design

Iterating the Conceptual Information Flow Diagram for the initial NIREUS Federation, several simplifications and one elaboration occur. Air and sea environment data will be inherent to ship and air vehicle motions. For ship topside geometry, only the landing zone plane needs to be represented at runtime, and its motion can be preprocessed. Likewise, ship motion and ship air wake can be preprocessed.

Despite its central importance to the operational problem, the coupled air wake between ship and air vehicle is daunting to calculate offline, let alone at runtime. There is no existing model readily leveraged for this component. Therefore, a vast simplification will occur for the initial NIREUS Federation, but a placeholder should exist within the design to accommodate more complex models developed in the future.

The VTOL tie-down problem can be solved as post-processing calculation, and can be eliminated from the runtime Federation. The pilot actions are tightly coupled to the air vehicle flight dynamics, implying both in one federate or at least interactions vice a publish/subscribe relationship. More than 'VTOL parameters' will be necessary to initialize the Federation, such as initial scenario geometry, ship identity, and perhaps sea/wind state selection. Thus, a specific scenario definition function is required.

Interestingly, air vehicle touch down is the more important (vice coupled air wake) system interoperability issue for the initial NIREUS Federation to address. The VTOL touch down function is to monitor the relative distance and orientation of the ship landing zone plane and the air vehicle landing strut plane. It is nominally assumed the ‘touch down monitor’ will receive non-uniform rational B-spline (NURBS) representations of the landing zone plane and landing strut plane. With these, it will perform calculations for intersection, relative distance, and angle off normal between the planes. Its job is expected to be a victory/defeat declaration for the landing operation. Depending on the landing system, victory may be declared at intersection or when the relative distance falls below a threshold. Defeat may be declared when the angle off normal (air vehicle tilt) exceeds a safe maximum, or when the air vehicle drifts outside a specified safety zone within the landing area. The touch down monitor, therefore, declares the end state for the Federation.

A probable additional federate will be one which computes the force exerted on the struts at touch-down. This calculation is required for two purposes: (1) If the upward force is large enough, the aircraft (e.g., a small UAV) may be “batted up” off the deck, requiring the simulation to continue; and (2) determination of any damage to the aircraft under-carriage.

The preceding analysis results in the nominal NIREUS Federation Design presented in Figure 2.

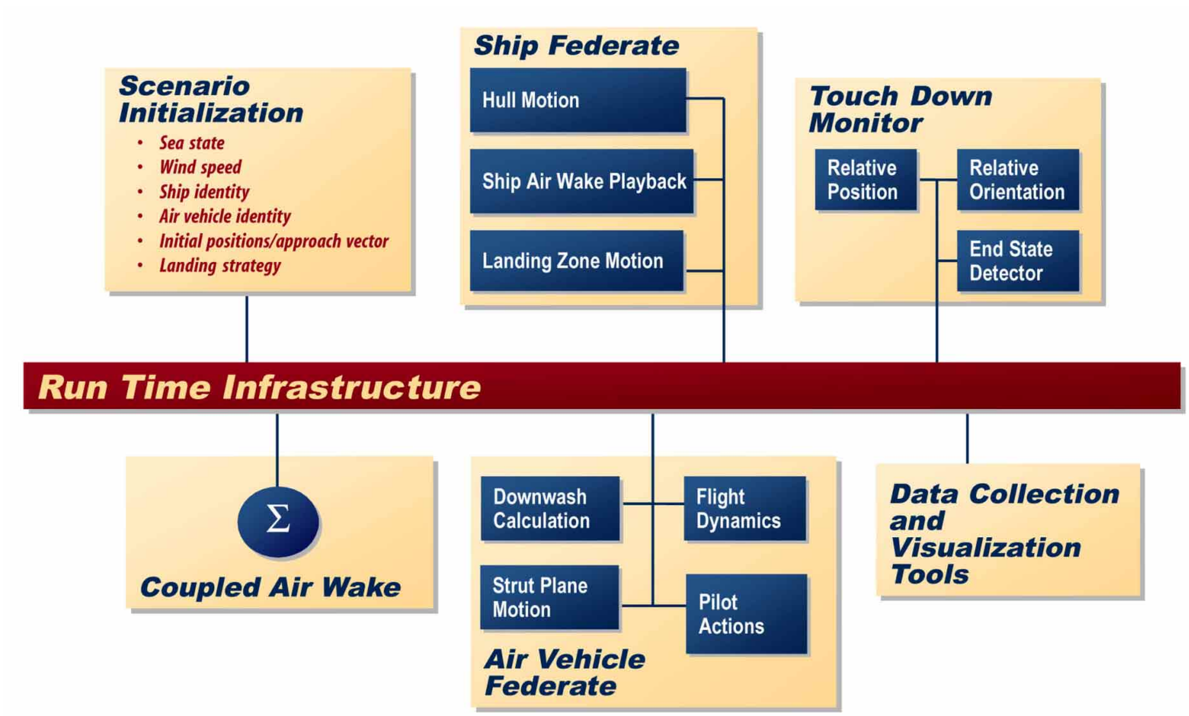

Figure 2. Nominal NIREUS Federation

In this design, a single ship federate can be used to publish data on ship position, ship hull motion, ship air wake, and landing zone motion. The air vehicle is also represented by a single federate, with the pilot subsumed within. A very simple coupled air wake federate performs a linear sum of the air vehicle downwash and ship air wake, which is published back out for use by the air vehicle federate. This calculation is too simple to justify a stand-alone federate, but it acts as a placeholder in anticipation of a more realistic set of algorithms in the future. The touch down monitor is shown as a separate federate containing the functions previously discussed.

The scenario initialization federate assumes that ship type, air vehicle type, scenario geometry, landing criteria, and natural environment conditions are variable selections at runtime. Other management, data collection, and visualization tools will be integrated as necessary.

The actual NIREUS Federation design is forthcoming in 2000, produced by the multi-national team. It is likely to look much like the nominal design, but may, for instance, subsume the coupled air wake calculation into the air vehicle federate. And, of course it will contain much more detail about the actual models and algorithms to be implemented. The purpose of the nominal Federation Design is to help facilitate discussion among the international team members and help the team continue progressing through the HLA federation development process.

5. Conclusion

The NIREUS study and its implementation as a HLA federation is scheduled for completion in September 2001. The ten NATO Nations and Partners participating in this collaborative effort hope to advance the understanding of an important and dangerous military operation. Ultimately, the hope is that ship and aircraft designs can be improved by accounting for this operation, and that safe landing envelopes can be expanded, thus improving military effectiveness and safety. In the near term, NATO will reap the benefits of this multi-nation collaboration.

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Author Biographies

MYLES M. HURWITZ is the Head of the Computer Modeling and Simulation Dept. at the Carderock Division of the Naval Surface Warfare Center, formerly known as the David Taylor Model Basin and David Taylor Research Center. He has been with the Carderock organization for 33 years in the research, development, and application of a wide range of warship HM&E simulation based design and virtual prototyping technologies.

Mr. Hurwitz's Department is currently focusing on several components of the Dept. of Defense Simulation Based Acquisition Initiative, including: ship design tool development; development and application of computational mechanics methodologies; integrated product data environment development and applications; product data standards; and high performance computing systems operations at the Navy's Hydrodynamic/Hydroacoustic Technology Center.

RICHARD A. READING is a senior engineer with VisiTech, Ltd. He is currently providing technical leadership and support to HLA federation developments for NIREUS and Navy ship combat system testing. Mr. Reading served as the system engineer for the Navy PEO Theater Surface Combatants HLA Pilot Program. Previously, he spent over ten years at the Naval Research Laboratory developing hardware and software simulations for surface ship electronic warfare systems development. Mr. Reading holds an MS in electrical engineering from The Johns Hopkins University, and a BS in electrical and computer engineering from Drexel University.